

# The Thermodynamics of a Ramjet

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Fig. 1: A NACA engineer cleaning a Ramjet circa. 1950 [1]

## I. INTRODUCTION

A Ramjet is an airbreathing engine which uses forward motion to compress air against a static conical compression. As such it can only generate thrust when already in motion. A typical ramjet operates from speeds of Mach 3 to Mach 6. This report will analyse a Ramjet through the lens of thermodynamics, using idealised Brayton cycles to dissect the sections of the jet and the state variables at each section.

## II. THE BRAYTON CYCLE AND THE RAMJET

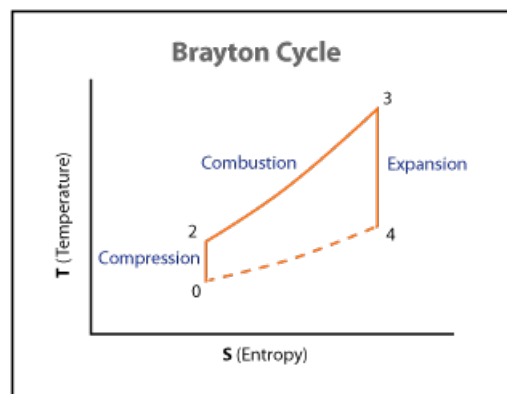


Fig. 2: An idealised Brayton Cycle [2]

To aptly define the air, henceforth referred to as the working substance, it must be noted that the air of the atmosphere is comprised primarily of Nitrogen and Oxygen gas. Both gases are diatomic and, for the purposes of this report, can be considered to behave like ideal gases.

#### A. Inlet and Compression

The inlet of the Ramjet consists of a diffuser which extends beyond the lip. Shock-waves at the tip of the diffuser causes the working substance to lose energy as it enters the inlet. The working substance is slowed to Mach 1 by this process. [3] As the working substance travels down the inlet, it is slowed to almost stationary. This compression of the working substance is considered to be adiabatic and reversible.

$$dV < 0$$

$$dQ = 0$$

$$dS = 0$$

where V, Q, and S are Volume, Heat, and Entropy respectively.

#### B. Combustor and Combustion

#### C. Nozzle and Expansion

#### D. Heat Rejection and cooling

### III. CONCLUSION

#### REFERENCES

- [1] "Naca technician cleans a ramjet in 8- by 6-foot supersonic wind tunnel." [Online]. Available: [https://images.nasa.gov/details-GRC-1950-C-25677?fbclid=IwAR1I4ILNCj8oFRWki7opYtk2FaSyQSROFKWyJmHVG05pxn6B\\_ouRdWINMkY](https://images.nasa.gov/details-GRC-1950-C-25677?fbclid=IwAR1I4ILNCj8oFRWki7opYtk2FaSyQSROFKWyJmHVG05pxn6B_ouRdWINMkY)
- [2] "Jet propulsion/thermodynamic cycles." [Online]. Available: [https://en.wikibooks.org/wiki/Jet\\_Propulsion/Thermodynamic\\_Cycles?fbclid=IwAR2LLB9xj9sYifvgjftlIzhw5BSKzmoTz6c3fQtq5W\\_v2dpcKOOxem0cEE](https://en.wikibooks.org/wiki/Jet_Propulsion/Thermodynamic_Cycles?fbclid=IwAR2LLB9xj9sYifvgjftlIzhw5BSKzmoTz6c3fQtq5W_v2dpcKOOxem0cEE)
- [3] M. Ou, L. Yan, J.-f. Tang, W. Huang, and X.-q. Chen, "Thermodynamic performance analysis of ramjet engine at wide working conditions," *Acta Astronautica*, vol. 132, pp. 1–12, 2017.